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Article

Developing a Design-Led Approach for the Food-Energy-Water Nexus in Cities

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Abstract

Urban communities are particularly vulnerable to the future demand for food, energy and water, and this vulnerability is further exacerbated by the onset of climate change at local. Solutions need to be found in urban spaces. This article based around urban design practice sees urban agriculture as a key facilitator of nexus thinking, needing water and energy to be productive. Working directly with Urban Living Labs, the project team will co-design new food futures through *the moveable nexus*, a participatory design support platform to mobilize natural and social resources by integrating multi-disciplinary knowledge and technology. *The moveable nexus* is co-developed incrementally through a series of design workshops moving around living labs with the engagement of stakeholders. The methodology and the platform will be shared outside the teams so that the knowledge can be mobilized locally and globally.

Keywords

energy; food; moveable nexus; nexus thinking; participatory design; urban design; water

Issue

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1. Introduction

This is a century of cities (Nature, 2010). More than 50% of the world’s population lives in cities, and this number is expected to reach 68% in 2050 (UN, 2018). As a result, the demand for food, energy and water (collectively referred to as FEW) as well as land is expected to increase even more, leading to concerns about crossing critical thresholds of capacity at all scales (Hoff, 2011), and eventually exceeding planetary limits (Steffen et al., 2015). In developing countries, it can be a challenge to shelter an adequate quantity and quality of FEW from environmental pollution and ecological system degradation (Abdul, Shrestha, Pandey, & Anal, 2017; NDRC, 2008; Siddiqi & Anadon, 2011). In developed countries, where the social

infrastructure is generally well-developed and living environment is maintained, FEW issues are not typically discussed as day-to-day concerns. Citizens mostly see FEW provisions as a given, and often do not show any particular interest except the bills, although both in regular times as well as in preparation for disasters and accidents governments and urban utility sectors are constantly challenged to be able to provide stable, sustainable and prevalent FEW services (Romero-lankao, Mcphearson, & Davidson, 2017). Recently, with progressing climate change, aging population, and deteriorating infrastructure, there is a growing awareness of risks to the sustainability of FEW in cities (IPCC, 2014; Moss et al., 2010), in the developed world (IRENA, 2015; White, Wutich, Larson, & Lant, 2015).

Sustainability of cities has been studied for long. However, the prevailing model of urban sustainability is too narrow (Powell, 2016). Planners and designer often work on sustainability, driven by specific techniques such as a smart energy system, the Edible City (Bohn & Viljoen, 2011), or design of green paths and rooftop gardens (Engelhard, 2010), etc., motivated by professional skills. Policy makers usually address single issues in a single administrative division even though the social, economic and ecological factors that present as problems of sustainability are in fact intertwined at all scales (Powell, 2016) and across sectors. The awareness of a nexus in FEW sectors is often weak. In fact, FEW are highly intertwined, even parametrically related. There are trade-offs and synergistic effects (Haase, Haase, & Rink, 2014; Vogt et al., 2010). This situation is referred to as the FEW-nexus. Due to the connectedness of FEW in social and ecological systems, a nexus approach could improve sustainability in general terms and, as a result, has attracted attention as a way to challenge the complex urban issues related to the status quo (Liu et al., 2018). The idea can be traced to works by Ignacy Sachs in the late 1970s and early 1980s, in particular with reference to the food and energy nexus at the United Nations University Food-Energy Program (Sachs, 1980, 1988). The World Bank worked on the food, water and trade nexus (McCalla, 1997) and later replaced the idea with new concepts, including virtual water, at the Kyoto World Water Forum in 2003 (Allan, 2003a; Merrett, 2003). The importance of the three nexus pillars of FEW was officially recognized at the first Nexus Conference in Bonn, Germany, 2011 (Hoff, 2011), making that year Nexus Year One. Since then, our understanding on the nexus has been seriously improved. The essence of the nexus thinking is about doing more with less by improving the efficiency of investment in resources and land-use (Hoff, 2011; Kurian & Ardakanian, 2015; Martínez-Martínez & Calvo, 2010). Understanding and acting upon this concept is central to diminishing the human footprint on planetary boundaries (Kurian & Ardakanian, 2015). However, “the application and implementation of a nexus approach is in its infancy” (Liu et al., 2018). This is particularly true in urban contexts. Most research is focused on the supply side of the equation, namely on how to secure FEW resources in response to a growing global demand. Few studies delve deeply into urban space and design solutions from the perspective of end users and consumers.

Working on sustainable solutions for FEW requires a strategic understanding of the urban nexus. The European Union initiated the Urban Nexus Project in FP7 (the 7th Framework Program, funded by the EU Research Funding 2007–2013) from 2011 to 2014. The project examined urban issues through a nexus approach and published a series of reports. The major finding of the project is that FEW in cities is not only an issue of resources but also of land use, resilience, and eventually the quality of life of a city’s urban populace (Urban Nexus, 2013a, 2013b, 2013c). FEW is a wicked problem

in consideration of the complexity of cities and related to many urban problems. However, governmental sectors or utility agencies typically treat the problems as independent issues (Bettencourt & West, 2010), and it is rare food, water and energy is dealt with together. Each sector generally has its own system, making it difficult to act in a broad and integrated way. When it comes to the environment, some argue that considerable efforts have already been made and that efficient resource use has been achieved so there is little room for further improvements.

Design-led approaches have the potential to break that mold. Design is by its nature a trans-disciplinary approach to problem solving, which draws upon logic, imagination, intuition, and systemic reasoning in order to explore potential innovative solutions to problems (Kimbell, 2011). Designers explore concrete integrations of knowledge that will combine theory with practice for new productive purposes (Buchanan, 2010), integrating the opinions and needs of multiple stakeholders. In spite of the romantic image that design is a highly personal process, in most cases design proposals are in fact the culmination of shared knowledge and consensus on a specific issue (Kimbell, 2012). These advantages make a design-led approach particularly appropriate to addressing wicked problems. The integration of FEW is not yet mainstream, and there is no established design methodology in practice. The nexus approach with regards to FEW in particular was not common in urban planning and design because of the complexity of the problem per se, the uncertainty of outcomes, and the difficulty of communication between scientific research and design as it is practiced.

This article proposes a design-led approach through the concept of the moveable nexus. The goal is to mobilize natural and social resources in urban spaces with integrated technology and knowledge in order to uncover and carry out FEW management innovations. It is also a response to the Sustainable Urban Global Initiative (SUGI) by the Belmont Forum and the Joint Programming Initiative Urban Europe in their call for the FEW-nexus (SUGI, 2016). In their words they ask us “to move stakeholders to action through dialogue from a sector oriented technocratic approach to one that recognizes more diverse viewpoints and rationalities” (SUGI, 2016). The moveable nexus is a methodology that helps designers and practitioners structuring the procedures, knowledge and techniques in design practices with regards to FEW. It is also a moveable platform to deliver the accumulated methods and techniques across cities and countries with regards to practice. We will discuss the essence of the moveable nexus concept, and the planned method for its development through the Belmont Forum joint research project. In Section 2 we will describe the key issues of urban FEW. In Section 3 we look at the components of the moveable nexus. In Section 4 we describe the procedure for implementation, and finally offer preliminary conclusions in Section 5.

2. Key Issues in Urban FEW-Nexus

2.1. *The Challenges to Modern Cities*

Cities are premised upon high population concentrations, accompanied by the conversion of land, originally used for FEW, into industrial activity. The rationality of modern cities was economic efficiency rather than the quality of life. The role of FEW was not diminished in the urbanization process but was dispersed and decentralized. Citizens enjoy greater convenience in daily life, but they become more remote from FEW resources (Loftus, 2009), causing a metabolic rift (McClintock, 2010; Sanyé-Mengual, Anguelovski, Oliver-Solà, Montero, & Rieradevall, 2016; Tornaghi, 2014). The limits of development and growth become manifest. Increasing climate change disasters and environmental pressures cast shadows on the sustainability of the conventional development model and in many ways force us to look back to basic concepts. Our cities will be not sustainable if we cannot step away from our path dependency in multiple aspects of our urban life (Bai, 2018; Romero-lankao et al., 2017).

2.1.1. Cities Are Gluttons for Resources

As an example, depending on the definition of urban areas, about 50% of the world's urban population consumed two-thirds of the total energy used globally, and are responsible for more than 70% of energy-related carbon dioxide emissions (Nature, 2010). Estimates of energy consumption by urban buildings and industry range between 37% and 86% and estimates of gasoline and diesel consumption attributed to US urban areas range between 37% and 77% (Parshall et al., 2010). In most countries, citizens are dedicated to driving, especially those living in suburbia. People rely on cars to meet their basic needs. Families prefer a large house in a new subdivision at the edge of town because they can get there by car. A job across town, remote from where people live and not served by public transit, is just as good as a job nearer to home even if there is a time and financial cost trade-off. Finally, cities become the major driving force to global warming and climate change risks because of the intensity of agglomeration. In light of the recently adopted Paris Agreement on climate change it is necessary to cut global CO₂ emissions by 50% by 2030, and by 80% by 2050, in order to limit global average temperature rising to 2°C or less by the end of this century (Rogelj et al., 2016), recently more ambitious to 1.5°C (IPCC, 2018). The path towards this goal is clouded but there is no time to wait. Cities, as the most prosperous places on the planet, and as the most intensive contributor to CO₂ emissions, will need to play a key role in emission reduction (World Bank, 2018). Viewed from the other side, the high concentration of production and consumption patterns in cities offers opportunities for human society to improve economic efficiency through transformative actions.

2.1.2. Cities Are Vulnerable

Our cities, and the systems that support them, have not been designed to address the FEW-nexus. Modern cities were established on a modernist understanding of urban life as an essentialist reality separate from rural life, and urban planning distinctly separated local agricultures as obsolete in a futuristic and normative understanding of the city (Barthel & Isendahl, 2013). Zoning systems exclude farmland and farming activity in urbanized areas, encouraging land owners to convert their lands to industrial, commercial or residential uses in many cities (Yokohari & Amati, 2005). Consequently, FEW are transported from distant places, while indicators such as food mileage (Tanaka, 2003), CO₂ emissions (Munksgaard, Pedersen, & Wien, 2000), and virtual water (Allan, 2003a, 2003b) usage steadily rise. Food, water and energy, from production to distribution to consumption and waste treatment are operated by different sectors. Moreover, as currently organized, the relationships between food, water, and energy are not yet mutually beneficial. Instead, they typically exhaust one another. Routinely, urban dwellers are enjoying the conveniences of urban living, and fulfill every need easily, from clothing to food and housing. Superficially, it seems as if FEW can be obtained easily as long as it is paid for. However, accessibility to FEW is in fact dependent on intensive infrastructure, a complicated supply chain of goods, and personal mobility. The intense concentration of populations, consumption activities, critical infrastructures, and social needs in metropolises assume that every part of that infrastructure will continue to work effectively into the future, with very little redundancy (Yan & Galloway, 2017). That implies that they are more vulnerable to natural hazards than distributed systems (Artioli, Acuto, & McArthur, 2017; Carpenter et al., 2015).

2.1.3. Cities Are Tarnishing

In the last century, in a surge of industrialization and urbanization, massive numbers of people migrated to cities from rural areas in search of a better life. This is now a global and continuing process. However, urban life has not spontaneously improved even as cities grow and their economies thrive. We have witnessed the winners and losers in the past decades of globalization and automatization. A majority of residents suffer from long distance commuting, traffic congestion and heavy workloads in megacities. Slums, crimes and poverty are synonymous in some cities. There is considerable overlap between the 1.1 billion poor people who lack access to adequate water and food, and the 1.5 billion who are without access to electricity (and to some extent the 1 billion slum dwellers in the developing world's cities) (Hoff, 2011). The situation in the so-called developed world is getting worse because of aging and other problems. For instance, the number of people living in food deserts is rising—around one million in the UK (The

Guardian, 2018), more than 7 million in Japan (Choi & Suzuki, 2013), and even more in the USA (Walker, Keane, & Burke, 2010). The cause can generally be attributed to handicaps, unaffordability or aging (Lawson, 2016). This is an entirely new challenge for the provision of quality FEW services in a period of growing inequality.

2.2. *The Essence of Nexus Thinking in Urban Design*

Nowadays, cities are considered places for better life though, as aforementioned, challenges toward sustainability are crucial too. It's true from the global perspective that FEW resources are indispensable for survival, and their conservation and efficient use are necessary for the sustainability of society. However, there exist gaps in awareness of the severity of the issue and the roles of stakeholders at human scales. FEW resources are tangible, and the nexus can be thought to be most inherently visible in nature and in rural communities, simply because the resources are used more directly in both life and work in these locations. Once FEW resources are delivered to cities where they are separated into sectors such as food, water services, electricity, and gas. For urban residents, FEW provides the basis of living, as well as the services provided by governments and businesses. The connection is less immediate, however. Very often, citizens have only been approached as either "receivers" or "users" which implies a passive role. They are not aware of the interrelations of food, water, and energy, and therefore will not change their behavior. To date, most of the FEW researches have been conducted at the macro-level. Accordingly, the urban basis for nexus policy and analysis remains weak (Artioli et al., 2017). Urban plans rarely address the FEW-nexus directly except to assume that continuing access to each aspect will be assured without any special additional measure. Because of this path dependency it can be said that the assessment tools, models, and policy recommendations of many planners seldom build on the nexus of FEW resources. Conventional planning, design, and governance systems struggle to meet the supreme position that cities have taken, namely as the most prosperous places in the modern world.

FEW-nexus thinking provides a tool to rethink the fundamental needs of human society, production and consumption, demand and supply, and cost and benefits etc. Instead of defining FEW as resource security, the FEW-nexus in cities should integrate its components into urban space and by doing so, turn the supportive aspect into a mainstream element that could create new opportunities (Kurian & Ardakanian, 2015). The essence of nexus thinking can be found in three guiding principles (Hoff, 2011):

1. Invest in ecosystem systems to secure FEW provisions;
2. Create more with fewer environmental costs;
3. Ensure accessibility to food, water and energy to all residents.

Implementation of these principles relies on finding solutions to the question: where, how, and who will produce food for cities?

2.2.1. Where—The Relationship of Production and Consumption

Typically, modern cities spread over wide areas. Spatially speaking, sustainability research and policymaking should shift focus from city centers to urban regions and global networks of production, consumption and distribution (Powell, 2016). In San Francisco, most of the carbon emissions associated with the consumption of goods by residents, firms and governments in 2008 were created outside the city's limits—elsewhere in the USA or overseas—"yet municipal sustainability initiatives target only the metropolitan area" (Powell, 2016).

Nexus thinking recognizes that production, distribution and consumption crosses both scales and places. The FEW-nexus is nested in multiple spatial scales (Verborg, Mertz, Erb, Haberl, & Wu, 2013). The extent of the potential of local production for local consumption depends on how and to what extent the distances between production and consumption can be reduced. This does not mean that every place should be self-sufficient and independent. Every city is unique in its land, its people, and its relationships to its ecosystems (Stead & Pojani, 2018; Thomas et al., 2018). Resources and flows are similarly different in every city and area around the world. Trading is still an efficient way to mobilize local resources and add value to commodities (FAO & UNEP, 1999). The question is to find an appropriate scale to work at with regards to the provision of FEW to all communities. Depending on location it may be regional or entirely local.

Regarding scale, the singular problem is how to scale up small activities to have large impacts. Various initiatives can be seen around the world that make use of FEW linkages, such as solar sharing, small hydropower generation, local production for local consumption, plant factories, community gardens, urban farming, and so on (Hussey & Pittock, 2012). Many of these are unsustainable as they are designed for a small number of people or are on a small scale and lack support. A design-led approach leads naturally enough to designed solutions, evaluates marginal benefits, and presents mechanisms that can be used to actualize the ideas. The proposition of the design-led approach is to propel a synchronized outcome, developing symbiotic relationships between FEW. Instead of siloed concepts from production to consumption, stakeholders should emerge as prosumers. These persons and groups collectively will own urban spaces and co-design circular solutions at different urban scales.

2.2.2. How—The Relationship between Costs and Benefits

Costs and benefits are the most critical aspects for sustainability. However, this is not an issue of profit or

costs itself. For instance, car dependent life brings us convenience while causing the bulk of CO₂ emissions (Farr, 2012, p. 23). It is a personal lifestyle, and in some ways a representation of moral value (Al-Saidi & Elagib, 2017). Reducing environmental costs while keeping the same lifestyle requires awareness of and contribution to common values (Ames & Herschok, 2015), and especially a desire for the sustainability of society. As noted previously the largest portion of CO₂ emissions in San Francisco came from food and beverages produced outside the city center, where the consumers actually live (Bettencourt & West, 2010). Activities for sustainability happen every day and everywhere. Planners make city forms and transportation systems; designers work on buildings; citizens make home gardens; farmers devote to organic farming etc. Some are commercial-based while mostly might be not. Many of them enhance ecosystem services (Costanza et al., 1997) and contribute to shaping a common shared value (Gómez-Baggethun & Barton, 2013; Haase et al., 2014; Tratalos, Fuller, Warren, Davies, & Gaston, 2007). These values are not always clear to the people themselves, as it is a collective creation, made by local decisions. How to include new practices in planning and design so the quality and benefits can be expressed clearly (and visually) to all of residents of a city remains an unsatisfied challenge.

For urban residents, on the other hand, FEW themes appear as (private or public) services of the social infrastructure. Citizens seldom see the hidden sides of the workings of government or businesses. People generally tend to be most strongly interested in daily life and work issues affecting their own families, neighborhoods, cities and regions, and have less interest in things that are not short-term or connected to their own immediate benefit. In fact, most modern cities were established on centralized energy, water supply and treatment systems, and the maintenance of the infrastructure involves enormous costs. Consumers are usually not able to get the direct experience of FEW resources being physically interconnected. This leads to severe constraints for integrated urban FEW designs, especially in cities with high disaster risks, and drastic demographic or industrial shrinkage.

The second principle of nexus thinking is to create more with less. We do not yet know how easy or difficult it is to replace centralized infrastructure with small scale distributed systems. Smart cities and smart communities are popularly experimented with (City of Chicago, 2009; Gondhalekar & Ramsauer, 2017; Townsend, 2013; Wolsink, 2012) and may eventually lead to useful conclusions, but that time is still somewhere in the future. Most of the tests are technology-oriented, and focus on energy (Wongbumru & Bart, 2014). Some look to water (Venkatesh, Chan, & Brattebø, 2014), and few focuses on food or FEW-nexus themes (Gondhalekar & Ramsauer, 2017; Wolsink, 2012). To go further we will need a mechanism to ensure the natural costs are paid and to ensure that choices are beneficial to both ecosystems and human beings, individuals and businesses. The nexus ap-

proach tries to establish such a win-win approach in which urban resilience, citizens' health and accessibility to resources could be shaped as the common value outpacing the costs.

2.2.3. Who—Relationship between Working and Living

With the Industrial Revolution, the main source of wealth moved from the countryside into the city (Cusinato, 2016). Urban living has served as a symbol of material wealth so that younger people continuously migrate from the countryside, especially in developing countries (The Economist, 2011). In fact, the wealth of modern cities was built on the marginal effect of cheap labor forces and external costs to the environment. In many cities around the world, and especially in the West, cities have been designed according to a zoning plan that separates working and living places in order to preserve efficiency of land use. FEW systems under this regime are centralized and work at large scales. However, this established working-living style is collapsing because of globalization and automatization. Factories are moving away from expensive cities where there are cheaper natural and human resources, leaving polluted vacant land behind, as in the cases of Belfast or Detroit. New business may continuously emerge in place of the old but there is a tendency to require a different kind of worker, if not an outright reduction in the number of people needed for the enterprise. What can be done in a city without jobs? What to do with massive numbers of vacant houses, void lands, and decayed infrastructure in an aging and shrinking society (Thieme & Kovacs, 2015)? FEW offers some thoughts. For instance, feeding the city through urban agriculture has been widely discussed (Moreno-Peñaranda, 2011; Morgan, 2009; Mougeot, 2000; Tornaghi, 2014), and practiced popularly from rooftops (Engelhard, 2010; Whittinghill & Rowe, 2012), home gardens (Barthel & Isendahl, 2013), formal landscapes (Bohn & Viljoen, 2011) and shared farmland in peri-urban areas (Hara, Mcphearson, Sampei, & Mcgrath, 2018; Meeus & Gulink, 2008; Mok et al., 2014). It is too much to say that urban farming will solve the problem of job migration that has taken place as a result of globalization, however it is not impossible that the use of FEW-nexus planning could set the stage for an alternative form of future urbanism, where work and life are more closely inter-related, along with FEW production and use.

Taking this idea further, urban sustainability can be understood not merely an issue of environmental conservation but the future of urbanism and urbanized civilization. Cities, as the dominant settlements, the home of most people on this planet, should not only be a place for work but also for living and fulfillment. FEW, both as a fundamental demand and as an infrastructure, could be not only the provisioning service but also a carrier of social ecological memories in cities even by practicing FEW nearby small scales (Andersson & Barthel, 2016;

von Heland, 2011). Mobilizing the related FEW potentials could work as a trigger for urban regeneration, wealth redistribution and the improvement of well-being. The design-led nexus approach will integrate the nexus principles with urbanism, such as producing local consuming local in practice. Following on that work, design solutions will be transferred to action programs for the UN Sustainable Development Goals (SDGs) with the cooperation of producers that aim for the balance of beneficial economic effects and environment, citizens in search of a better living environment, and governments that seek to provide efficient public services.

3. Design-Led Nexus Approach

The design-led approach aims to develop FEW solutions in cities to mobilize the potential of natural resources at multiple scales, improving the efficiency of land and resources, delivering services to all who require it. There is no such thing as a one-size-fits-all solution to any problem amidst the diversity of local and global contexts. Therefore, design itself should be a process of learning, integration and communication. The moveable nexus is such a concept within this philosophy.

3.1. The Concept of the Moveable Nexus

Research and design practice on food, water, and energy by sector are not new. Rich knowledge is accumulated in each discipline. A huge amount of research has been conducted on the nexus-pairs of food–energy (FE), energy–water (EW; IRENA, 2015; Varbanov, 2014) and food–water (FW; White et al., 2015), climatic impacts (Carpenter et al., 2015; Johansson, Schmid Naset, & Linnér, 2010; White et al., 2015) or the three pillars of FEW (Endo & Oh, 2018; Endo, Tsurita, Burnett, & Orencio, 2014).

While nexus literature is long on determination and ambition, it is short on grounded evidence on the essential elements of FEW security, such as operational definitions that help to link research and practice,

particularly within urban systems. (Romero-lankao & Gnat, 2016)

Most of the previous studies view FEW issues from the supply side of resources, investigating the scientific mechanisms of material flows, predicting the increase of FEW risks associated with population growth and development. Typical examples include the survey of ecological resource availability (Daher & Mohtar, 2015), urban metabolism modeling of production, consumption and disposal (Bazilian et al., 2011), shifting to a low-carbon circular economy (Bears, 2017; Bhaduri, Ringler, Dombrowski, Mohtar, & Scheumann, 2015), and reducing external inputs from outside the region while encouraging local production for local consumption (Siddiqi & Anadon, 2011). However, scientific knowledge is not popularly applied in many of the design practices linked to the creation of the built world. Similarly, with some notable exceptions such as the Living Building Challenge, architects design buildings to save and manage energy, or work on the redevelopment of urban neighborhoods to improve livability. Landscape architects work on urban landscapes, urban agriculture and green infrastructure to create the feeling of a greener urban life. City planners study land use policy to improve efficiency of transportation and distribution. Quite often, participatory design in the literature is introduced as a kind of event-driven professional and educational activity, lacking the ability to transfer the gained knowledge to a large scale of practice. With regards to the FEW-nexus, each profession has a kind of limitation of scope that needs to be bridged both in breadth and in scale.

The moveable nexus is considered as an innovative methodological package for FEW management and utilization that make use of the spatial, temporal, and service linkages of natural and social resources. As the illustration in Figure 1, the package offers an indication as to how to practice nexus thinking in a way that will lead to its integration with urban planning, architectural design, and environmental policy studies. Ultimately it is a communication platform that can be moved to a design site with the support of scientific data and knowledge.

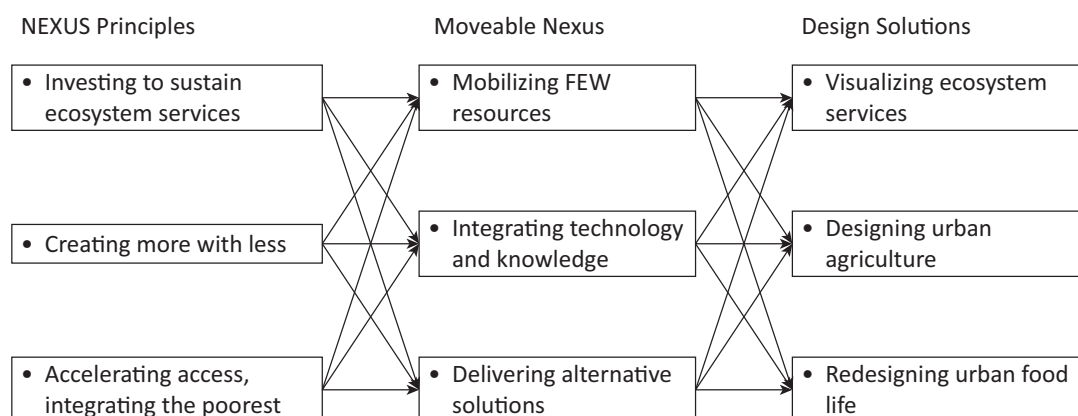


Figure 1. Principle of nexus thinking and moveable nexus. Source: authors.

3.2. The Development of the Moveable Nexus

The moveable nexus consists of design methods, evaluation tools, and participation mechanisms that can be used in design practice. The guiding principles for the development are described below.

3.2.1. Design Methods

The application of FEW-nexus and urban agriculture in cities could take a diversity of forms, including technology or policy, buildings or landscape, commercial products or public engagement programs. Design methods at the moveable nexus provide guiding procedures to explore solutions with stakeholders. The procedures of the design method construction consist, in general, of the following steps, as shown in Figure 2:

1. Inventorying FEW-related existing or potential resources and availability of space for urban agriculture, including rooftops, vacant houses, or abandoned, improperly used or void lands;
2. Designing solutions to improve the efficiency of land and space use for food production and ecosystem services with less energy and water consumption by integration of FEW technology and knowledge;
3. Composing the nexus matrices that mobilize the material and flows of resources cross sectors and disciplines in the social-ecological context;

4. Evaluating the environmental costs and the added benefits of the solutions through the enhancement of spatial, temporal and service connections among specific social-ecological systems;
5. Delivering the alternatives of solutions to and reiterate the design process with stakeholders.

This is co-design and a reflexive process with stakeholders. The inventory includes natural, social, financial, and industrial aspects. The mobilization of resources implies the activation and connection of existing and potential capitals across industrial, administrative and academic boundaries with more flows and services.

3.2.2. Evaluation Tools

The evaluation of design solutions is a tricky issue. There exists a long list of indicators to assess the impact of human activities on the environment, such as the most typical ones, food mileage (f), CO₂ emissions (e), virtual water use (w), Ecological Footprint (EF), etc. However, no such an indicator could properly describe the interaction of FEW.

EF (Wackernagel & Rees, 1998) converts the CO₂ emission in human consumption to land area equivalent to the area of forest demanded for absorbing the correspondent emission. We propose an indicator few-print which express the quantity of FEW resources to be consumed and the flow—that is, the service—among the three layers. The few-print is a combination of food

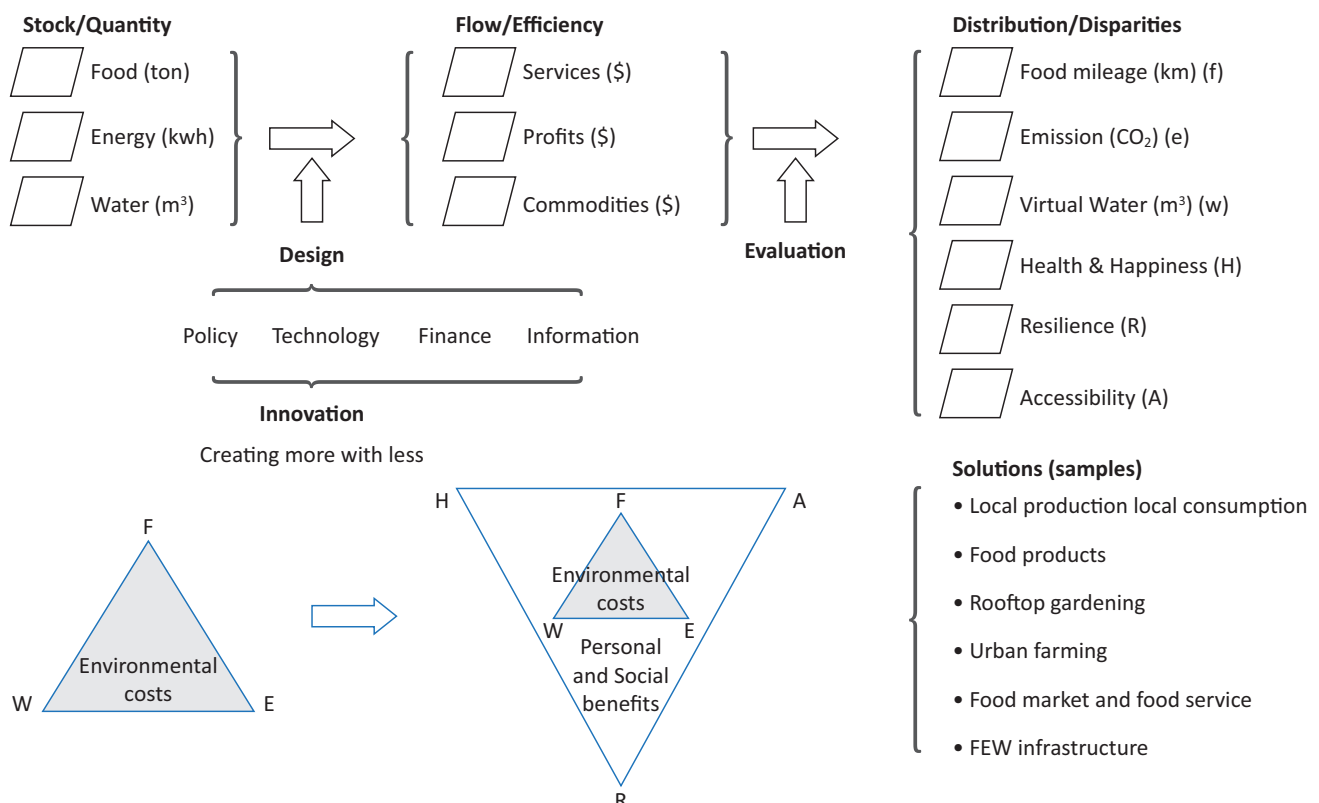


Figure 2. Framework of the moveable nexus. Source: authors.

mileage (f), CO₂ emissions (e), virtual water use (w). It also represents the ambition of nexus thinking: creating more with less.

On the other hand, the functions of urban agriculture are multifaced. People enjoy home gardens or shared farming not necessarily for the CO₂ reduction but rather for other benefits, such as education, health, culture and communication etc. Similarly, some new issues can emerge from the process, such as a reduced few-print that goes along with reduced accessibility to those resources by the residents of an area. Investors might also pursue common shared values with the public on urban agriculture and ecosystem services rather than on food production itself. Therefore, in addition to few-print, we incorporate three social indicators in perspective of citizens' quality of life: health and happiness (H), accessibility (A) and resilience (R), collectively referred to as HAR. Although each indicator has been intensively studied (for health and happiness see Groenfeldt, 2006; Urban Nexus, 2013a; for accessibility see Walker et al., 2010; for resilience see Magis, 2010; Mitchell, & Harris, 2012) the trade-offs and synergistic effects with environmental factors have not been examined.

The development of the few-print and HAR is a complex process in design. The numbers might mean different things as scales change from household, to city block to neighborhood, to the city and bioregion. The indicators of the moveable nexus in this way may not be perfect tools to judge the quality of solutions but more appropriate for communication. Stakeholders will need to understand the trade-off and synergy of different solutions at different scales so that each partner could rethink the relationships about costs and benefits, and their behavior.

3.2.3. Participation Mechanisms

Involving users in urban design and development has long been a core concept though practice is often different between social contexts (Bergvall-Kåreborn, Howcroft, Ståhlbröst, & Melander, 2010). "Through engagement with a product or service over time and space", Kimbell (2012) says, "the user or stakeholder continues to be involved in constituting what a design becomes". Designers explore concrete integrations of knowledge that will combine theory with practice for new productive purposes (Buchanan, 2010). "Design with users, design by users or design for users are popularly advocated within areas like innovation and product development" (Björgvinsson, Ehn, & Hillgren, 2012; Wahl & Baxter, 2008). However, how to sustainably involve stakeholders especially over the long term is not easy for any participatory project. There are examples, however, that tend to be self-selecting groups who have bought into a larger goal. The community involvement of residents in Freiburg, who collectively built their eco town over decades. People who move to Freiburg did so in order to be part of that process (Freiburg, 2018). Bringing otherwise regular people into design is a more challenging task.

In the moveable nexus, the participatory mechanisms are the collaboration process of four type of partners: intermediate support organizations, the local community, experts in spatial planning, and public or private sectors. Each partner owes specific resources and advantages such as physical spaces, skills, knowledge, financial or regulative options. Our understanding is that intermediate support organisations, mostly driven by local actors, play a key role to connect stakeholders together.

The engagement of the multiple stakeholders is conducted through a series of design workshops in the moveable nexus. All of the stakeholders incorporate equity into every stage of design process, from research to formulation (Powell, 2016). During the workshop, design experts visualize resources and produce solutions. Local community gain awareness of the issues and co-create the shared values. Private or public sectors could be inspired and then turn the plan and design into political and business actions.

The design workshops will be informed with scientific evidence. The moveable nexus provides a platform for communication and learning of stakeholders, in which the FEW resources and evaluation indicators aforementioned are installed. As the results, the design solutions incorporate the wishes and intentions of all of the participants and then fits a variety of action plans and projects, while enriching the physical and social resources that are unique to the region.

Finally, the moveable nexus itself is co-developed incrementally with stakeholders through the processes in practice. Urban Living Labs (ULLs) are used as a platform to implement/accommodate the contents of the moveable nexus and secure the sustainability of the practice.

3.3. Urban Living Lab for Practice

ULLs are initiatives that focus on the collaboration of multiple stakeholders (government, industry, research institutions and communities) in different stages of the research, development and innovation process (Thinyane, Terzoli, Thinyane, Hansen, & Gumbo, 2012). It is also a recommendation of funding agencies such as JPI Europe Urban. Over the decades, the concept of living labs has become widely accepted in design practice with design thinking and system thinking (Kimbell, 2011), shifting design from design "things" to design "Things" (Björgvinsson et al., 2012). Compared with regards to its popularity to open innovation, lead users, public health, IT tools, user-driven design (Bergvall-Kåreborn, Holst, & Ståhlbröst, 2009), it has only a limited success. Voytenko, McCormick, Evans and Schliwa (2016) surveyed five living lab projects granted by JPI Europe Urban and concluded that the concept was mostly used to secure funding. There remain many questions about the impacts and effectiveness of ULLs both in their own geographical domain and more broadly at regional and national scales. For example, how do ULLs evaluate their own impacts? How do they build on feedback results and findings of

evaluation to improve their activities and impacts? These questions are reminiscent of the problems outlined in Section 2. Researchers, designers and stakeholders have difficulties in communication with each other because of the gaps between scientists and citizens, long-term global goals and the short-term personal interests on sustainable issues as well as FEW issues. Answering the questions need a collaboration network working on common issues with a designated scheme.

The moveable nexus by its nature requires the bio-region-specific collaboration of stakeholders. On the other hands, the methodology and platform of the moveable nexus could be applied everywhere for the researcher, designers and practitioner who share common understanding. An ULL could be an existing one run by cooperative stakeholders or a new one initiated by researchers. With the support of a living lab, researchers could work strategically with stakeholders to co-design long-term strategies for urban productivity in light of changing contexts. The living labs created in research areas could be part of a global network for comparative studies.

Therefore, the moveable nexus and ULLs are complementary ideas each other. The former provides contents while the latter has advantages of practical platforms with stakeholders. The moveable nexus could also help ULL to move around with the shared contents, thereby enabling global deployment. In this sense, the moveable nexus could add new values to ULLs with integrated solutions for urban FEW managements.

4. Implementation

4.1. Research Sites

The moveable nexus was proposed as the core concept of the project “The Moveable Nexus: Design-Led Urban Food-Energy-Water Management Innovations in New Boundary Condition of Change” (M-NEX) granted by Belmont Forum and JPI Europe Urban. The purpose of the project is to show how topics and issues of FEW that span across diverse regions in the world can be studied within a uniform concept. A research consortium with seven organizations in six countries (Australia, Japan, the Netherlands, Qatar, UK, USA) has been established, with its study areas being Sydney, Tokyo–Yokohama, Amsterdam, Doha, Belfast, Detroit correspondently.

The geographical features, bioregional differences and social themes of every study area are summarized in Table 1. The cities differ in terms of geographical features, bioregions and societal conditions, but from the table it is clear all cities are mature and share several common concerns in terms of sustainability in their urban areas. The project will take the complex sustainability challenges of its involved cities, and communicate FEW design solutions in concrete, visual, and physical ways to stakeholders and residents. This will deepen the understanding of FEW and promote consensus-building on actions plans for future cities.

Each country team will determine the research contents in consideration of the local needs and proceed collaboratively. For example, the UK team (Belfast) will work on design of food factories, while the Dutch team (TUD) will focus on energy planning in FEW-nexus. All of the teams will learn from each other and study the potential to incorporate FEW-management into their own cities. Ultimately, they will deliver their research findings, policy recommendations and technical innovations, such as implementation of FEW at a University campus (Doha), revitalization of a post-industrial city (Detroit), and future FEW strategies for consumption-oriented cities (Tokyo–Yokohama, Sydney).

4.2. Working with ULLs

Each team builds an ULL in the study area, hold stakeholder and community design workshops, consider local FEW-topics, and develop solutions. The ULL in each city is featured with the local social and bioregional context.

4.2.1. Belfast

Northern Ireland has generally weak infrastructure and a very poor natural gas network due to the recent civil strife known as ‘the Troubles’. In supply side of food, a strong reliance on imported food due to heavily industrialized and dense beef and dairy farming, very little arable agriculture. On the other hands, a strong dependence on the car due to poor public transportation in conjunction with poor diets due to food poverty, leads to increasingly prevalent issues surrounding obesity and diabetes. The Belfast Living Lab is based in the designated Urban Villages project. This project funded by the Northern Ireland Assembly works in 5 of the most deprived neighborhoods in Northern Ireland, to facilitate sustainable development of these at risky groups.

4.2.2. Tokyo

The 2011 earthquake and tsunami in Tohoku revealed the vulnerability of modern cities. Many areas in Japanese cities were built in the twentieth-century post-war period of high economic growth and are now approaching a time when infrastructure and other upgrades will be needed. Japanese cities are also facing declining birthrates and aging of the population and becoming more compact, even as they face rapid changes on the spatial and temporal dimensions in terms of the supply and demand for FEW (Moreno-Peñaranda, 2011). The Tokyo Living Lab is going to work in cooperation with WISE Living Lab, a community-based project initiated by Yokohama City and Tokyu Corporation since 2012 in which WISE represents an acronym of Wellness; Intelligent and ICT (Information and Communication Technology); Sustainable and smart; and Ecology, energy, economy. In the summer of 2018 the Japanese government selected 29 municipalities as pilot SDGs model

Table 1. Overview of characteristics of partner cities and case study projects.

Partner City	Belfast (BEL)	Doha (DOH)	Detroit (DET)	Sydney (SYD)	Tokyo (TOK)	Amsterdam (AMS)
Main thematic	Divided city	Food security	Vacancy and Capacity building	Urban Development process	Ageing and disaster risk	Co-creation of spatial
Climate	Maritime	Desert	Continental	Subtropical	Subtropical	Maritime
Bioregion	Northern Ireland Bioregion	Arabian Desert Bioregion	Great Lakes Basin Bioregion	Sydney Basin Bioregion	Kanto Plain Bioregion	Atlantic Mixed Forest Bioregion
Scale	Neighbourhood	Precinct: Uni-campus	Metropolitan region	Large Greenfield: 3rd City	Roof / vacant land	Neighbourhood
FEW-focus	F: Diet E: Algae W: Flood	F: Local plantation lowering UHI E: Solar W: Drought, reuse	F: Urban production E: Waste to energy W: Great Lakes Basin	F: Regional food-bowl E: Large and small hydro W: Heat	F: Food in urban roof / rural E: Solar panel W: Water-river basin	F: High tech, vertical E: Wind & integrated renewables W: flood, controlled
Motto	‘The Aquaponic city’	‘The urban water machine’	‘The post-industrial city’	‘The fridge city’	‘WISE city’	‘The circular city’
Take away	Technologies	People Engagement	Regional synergies Scalar Cascades	Far future design	Regional integration	Design with flows for far future
Goal	Existing technologies in the city	Expanding the effectiveness of food production in the city with minimal water availability	How to overcome jurisdictional barriers	Using landscape as cooling machine through plantation, crops and water	Close FEW cycles at river basin level	Close FEW cycles at city level
Data	Baseline data	Place based data (QU campus)	Regional jurisdictional data	Regional landscape data	Building and land use data	Flows of FEW data
Method for workshop	Roadshow	Design workshop	Large scale spatial drawing	Creative COCD	GIS modelling	Stakeholder co-design
Paradigm shifts	2050–2080	2050–2100	2035–2070	2030–2060	2040–2080	2040–2070
Outputs	Part I of few-print Advanced FEW Technologies in the city into the future	Part II of few-print Community gardens and permaculture, for higher scales	Part III of few-print Jurisdictional system, Visualizing Cascading systems and scales	Part IV of few-print FEW-urban landscapes	Part V of few-print FEW-integration in local community	Part VI of few-print Energy cascading / REAP for Food and Water

projects including Yokohama City, started to tackle these issues (Cabinet, 2018). The M-NEX Japan Team is designing new management systems to secure the accessibility of urban FEW in the Tokyo-Yokohama metropolitan area plus sustainable improvements in the quality of life, and the necessary infrastructure to support all of that.

4.2.3. Sydney

It is foreseen the Sydney region will be confronted with a rapid increase in population in the next 20–30 years (Greater Sydney Commission, 2018). The number of people will almost double and reach a total of approximately 8 million people. To cope with this enormous change the regional planning authority (Greater Sydney Commission) has presented the region as a metropolis of three cities: the old Harbour city in the East, the central Parramatta river city and the newly to be developed Western Parkland city around the new Badgerys Creek airport (Greater Sydney Commission, 2018). The Sydney Living Lab will be the new Western Parkland City, around the new Airport of Badgerys Creek. The task is to explore what new type of city could emerge here, given the fact that current development processes often not lead to a very smart, resilient and sustainable outcomes, as these neighborhoods tend to have sparse green and trees, maximized housing space on plots, people commuting to the city and spend large amount on energy because of the need of air conditioners.

4.2.4. Doha

Qatar has limited water resources; the climate is too hot and dry for much agriculture; dust storms are a serious threat. It has the highest per capita emissions of carbon dioxide in the world because of free electricity and the reliance on energy-intensive desalination for potable water. Qatar is extremely vulnerable to rising sea levels and rising temperatures due to climate change. A recent embargo by neighboring states including Saudi Arabia, a major food supplier of Qatar, has heightened the necessity for more efficient and resilient food systems and supplies. The Doha Living Lab will be built on the existing Edible and Regenerative Campus project as well as on ongoing research and networks at Qatar University related to the FEW-nexus such as new food crops, halophytes and micro algae and reuse of water, etc., under the theme of the “The Urban Water Machine” with the engagement of all the University communities.

4.2.5. Detroit

Referred to globally as an example of post-industrial shrinking cities, Detroit has suffered from chronic socio-economic and race segregation coupled with income inequality that amplified de-population of the central city. The urban footprint of Detroit is vast (143mi²) in area and designed in parallel with the emergence of the auto-

mobile and models of single-family car ownership. Currently 22mi² acres of vacant residential and commercial land within the municipal limits. Extensive area of land is characterized as brownfields. While USDA (United States Department of Agriculture) metrics for food deserts point to a crisis of food access within Detroit, multiple alternative sources are emerging within the urban agricultural space. Community, NGO and larger organizations are undertaking urban agriculture practices and food hub production is increasing. This context is ripe for FEW-nexus based analysis. Which may assist stakeholders in catalyzing change while identifying multiple collateral benefits to water and biomass-linked processing practices. The M-NEX Detroit will work with the U-M Detroit Center as a Living Lab partner. Located in the heart of the city’s Cultural Center, the U-M Detroit Center serves as a gateway for University and urban communities to utilize each other’s learning, research and cultural activities.

4.2.6. Amsterdam

Amsterdam is dealing with climate adaptation issues and with the ambition to become climate neutral by 2050, as well as natural gas free. The city is still strongly reliant on food supply from elsewhere, as only a small share comes from the region. Schiphol Airport is a collection point of waste (food, water, materials), which is treated or incinerated elsewhere, far away. The Amsterdam Institute for Advanced Metropolitan Solutions (AMS) has The Circular City as one of their three key themes. AMS, an institute by TU Delft, Wageningen University and MIT, collaborates with the City of Amsterdam and local stakeholders, using the city as living lab for the transition to a sustainable future. The M-NEX Amsterdam is going to work in cooperation with the AMS Institute, the Amsterdam Institute for AMS. The M-NEX Living Lab will be selected and elaborated with AMS Institute and the City of Amsterdam, involving stakeholders from the city, public, private and individual to work together.

4.3. The Collaborative Scheme

The moveable nexus shall be developed incrementally through a series of design workshops at the above six living labs with all of the partners (see Figure 3). The project engagement will consist of six stakeholder workshops, one in each living lab that engage with key aspects of the FEW, in a bioregional context. This international workshop coincides with one of the (six) participatory workshops in each city. The international team will participate in this workshop and bring their particular skills and knowledge to it. Each of these international workshops has their own focus. The first workshop in Belfast (BEL) focuses on the creating an Initial vision on the technical food systems and the city. In the second workshop in Doha (DOH) the focus is on the city farm, stakeholder participation and urban agriculture. Workshop three (Detroit, DET) focuses on climate futures, de-

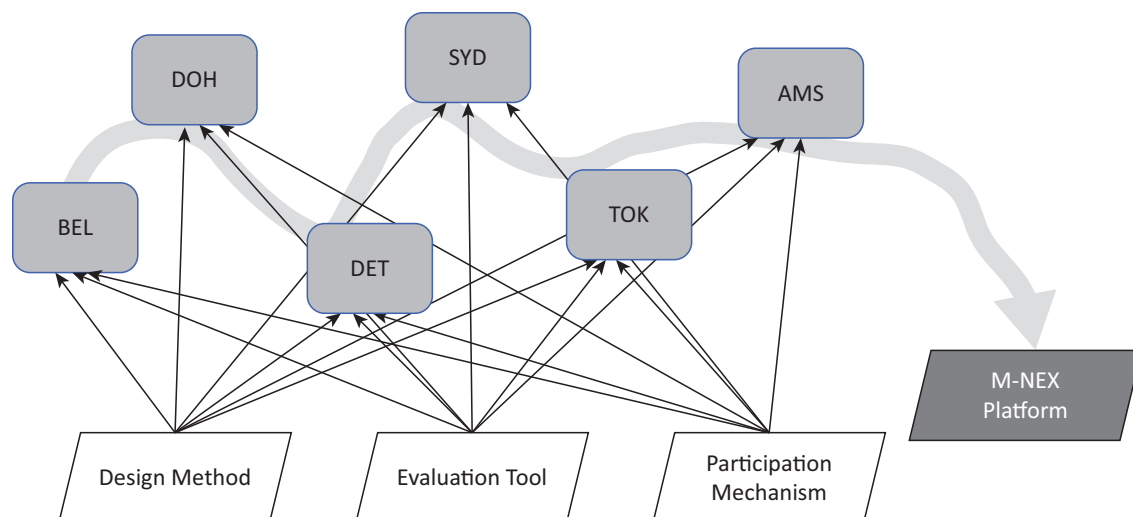


Figure 3. Scheme for the implementation of the moveable nexus.

velopment of regional scenarios and resilience in light of a changing climate. Workshop four (Sydney, SYD) focuses on building Integration, integrating FEW-technologies at user scale. Workshop five (Tokyo, TOK) focuses on stocks and flows for regional planning and the nested neighborhood. And the final workshop (Amsterdam, AMS) focuses on implementation, from strategy to tactics. Each team will bring its own topics to the international design workshop, and the teams together will refine them and build common design methods, evaluation indicators, and co-creation mechanisms. The teams will bring what they have learned back to their countries, put them into practice in their local Living Labs and undertake action toward the next international workshop. Finally, the knowledge obtained at each workshop will be integrated and provided as expertise and solutions from the M-NEX Project at each level, from building to neighborhood, city, and region.

5. Conclusions

The fact that environmental issues are indeed global in nature, gives reason to international collaborative research. Meanwhile, environmental problems are complex and require interdisciplinary efforts. With this awareness, the nexus approach is increasingly important. An enormous amount of effort is needed to create multinational and multi-sectoral research frameworks. Key issues to establish real integrative plans, projects and programs are the use of design-led methods and approaches, the implementation of early assessments, e.g., during the planning process and not afterwards, and finally the early, e.g., from the beginning, co-creative involvement of stakeholders and citizens in the planning and design phase of projects. The essence of the moveable nexus, the design-led approach is to facilitate the further integration of FEW in cities in an accessible way. Design is appealing to many and makes it possible to

visualize solutions and possible outcomes of the benefits of each FEW-part being each other's resource and service, so everyone can understand these abstract relationships hence be involved. It also makes it possible to assess the propositions at a very early stage, and this holds the opportunity to amend projects during the planning stage rather than after realization. Huge costs can be prevented.

The moveable nexus is defined with three meanings correspondent to the nexus thinking and the SUGI call:

1. To mobilize social and natural resources to create more with less for all the needed with design solutions;
2. To move stakeholders to action through cross sectoral dialogue with informed platform of M-NEX;
3. To move around local and global to the needed with the support of guiding principles and informed platforms.

Unlike the conventional approaches of research and practice, which try to deliver established knowledge and tools to users, the construction of the moveable nexus itself is through a series of design workshops which are open to any stakeholders. The three components of the moveable nexus shall be developed reflexively through engagement of stakeholders. The open idea has much adaptivity and applicability to diverse contexts while we should also keep mind the challenges in practices crossing cities (Stead, 2012; Stead & Pojani, 2018).

The concept of the moveable platform, the incremental development process, and the participatory workshops in a row are flexible to different research sites. It shares similar concept with urban living labs while the former focuses on contents and the latter has advantage of participatory platform. The collaboration of these approaches will create synergetic effects and demonstrate solutions for urban sustainability.

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Conflict of Interests

The authors declare no conflict of interest.

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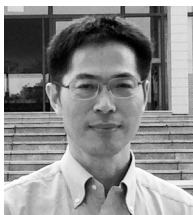
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